

# Geothermal Energy

**Clean, Base-Load Energy**

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# Geothermal Energy

- What is it?
- Where do you find it?
- How do you use it?

# What is Geothermal Energy?

**Geothermal. Geo (Greek, from GE, earth) + thermal (Greek, from therme, heat) = pertaining to the internal heat of the earth**

**Geothermal energy is conventionally defined as the heat of the earth**

**Geothermal resources are defined as concentrations of subsurface heat that can be extracted and used economically**

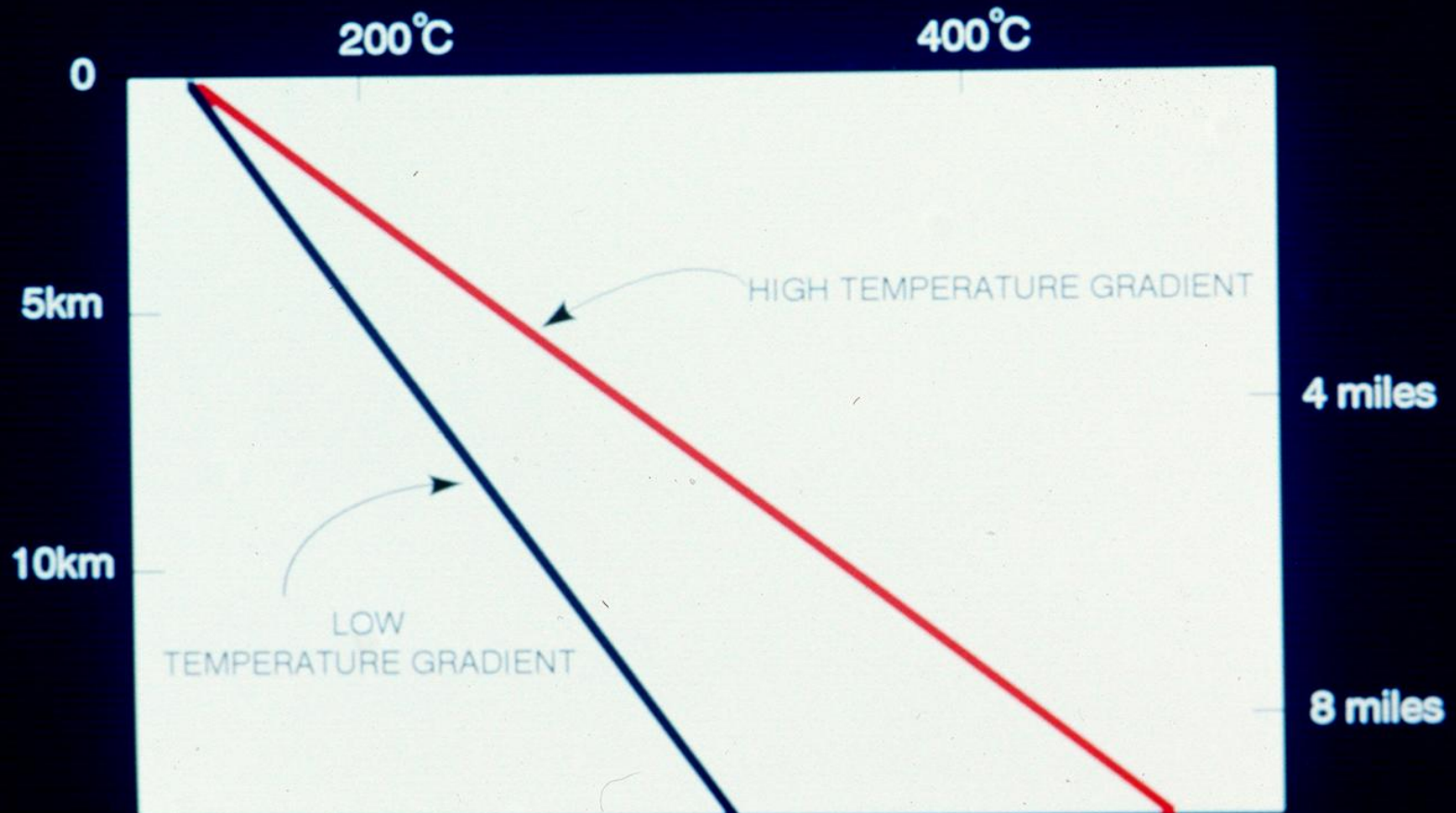








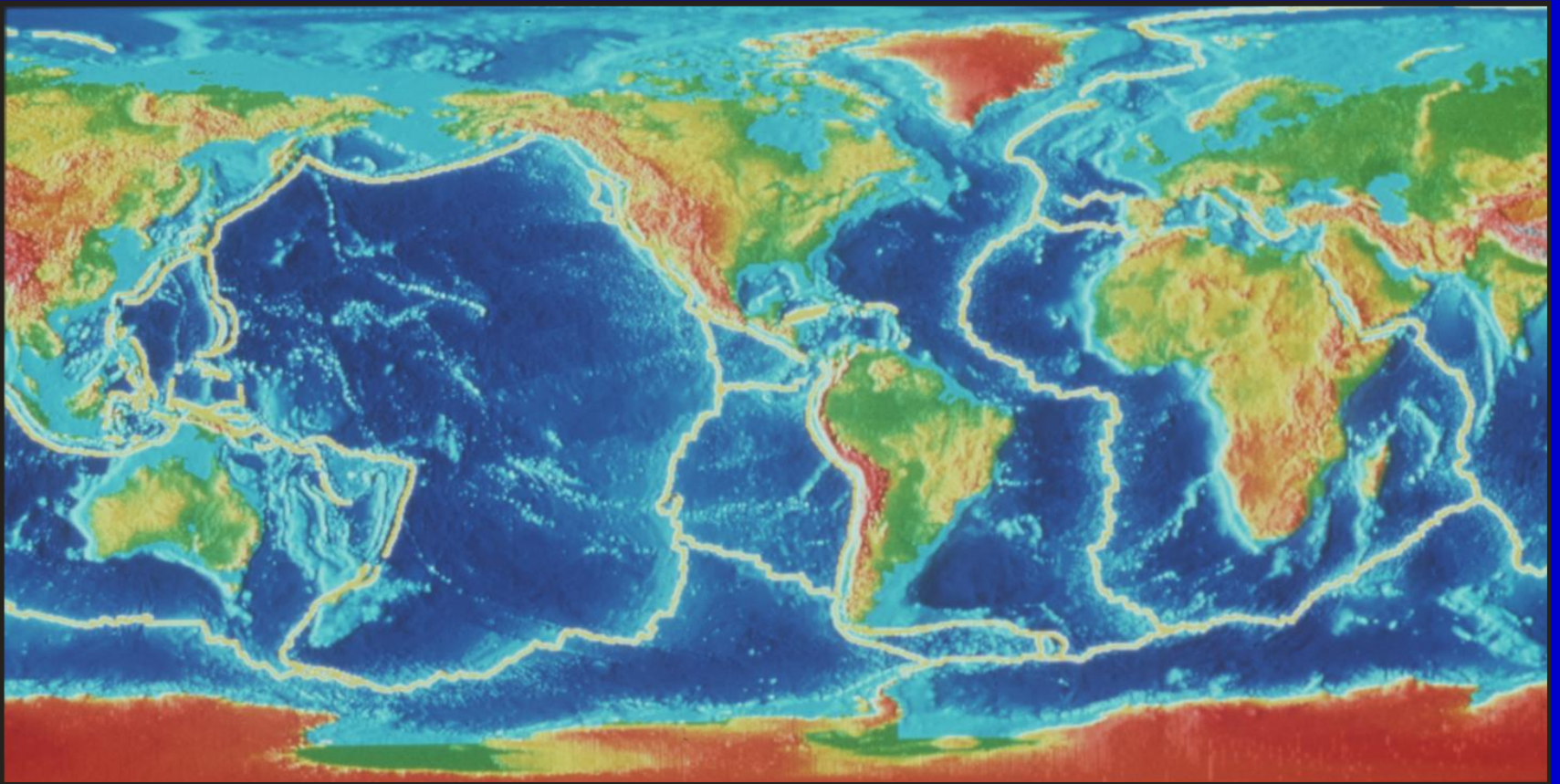
# Temperature vs Depth in Crust



# **Areas of Elevated Subsurface Temperatures/Volcanism**

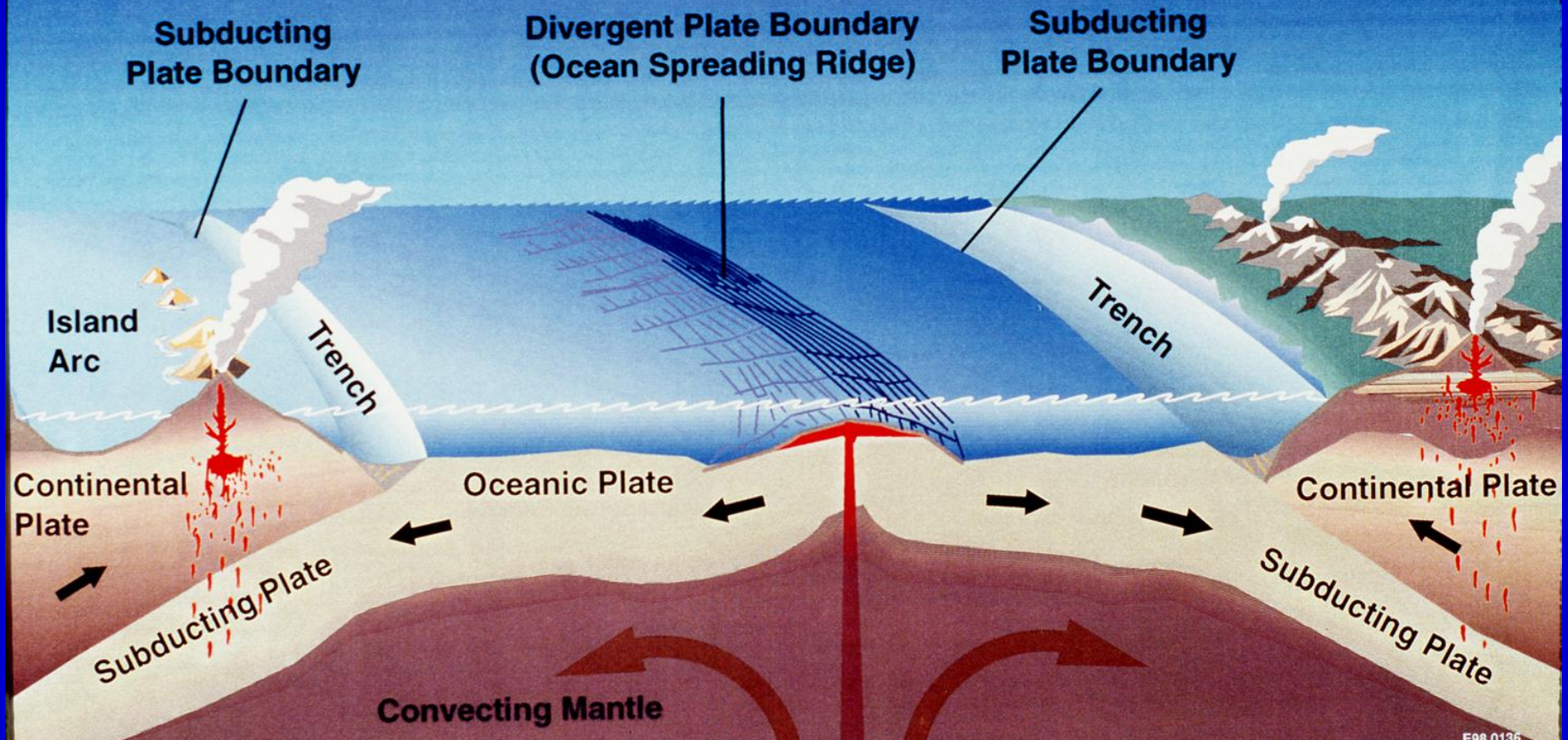
- **Plate boundaries**
  - Spreading centers – generally in oceans
  - Subduction zones
- **Hotspots – most notably**
  - Hawaiian Islands
  - Iceland
  - Yellowstone
- **And in US – crustal extension associated with plate boundary**

# Crustal Plate Boundaries



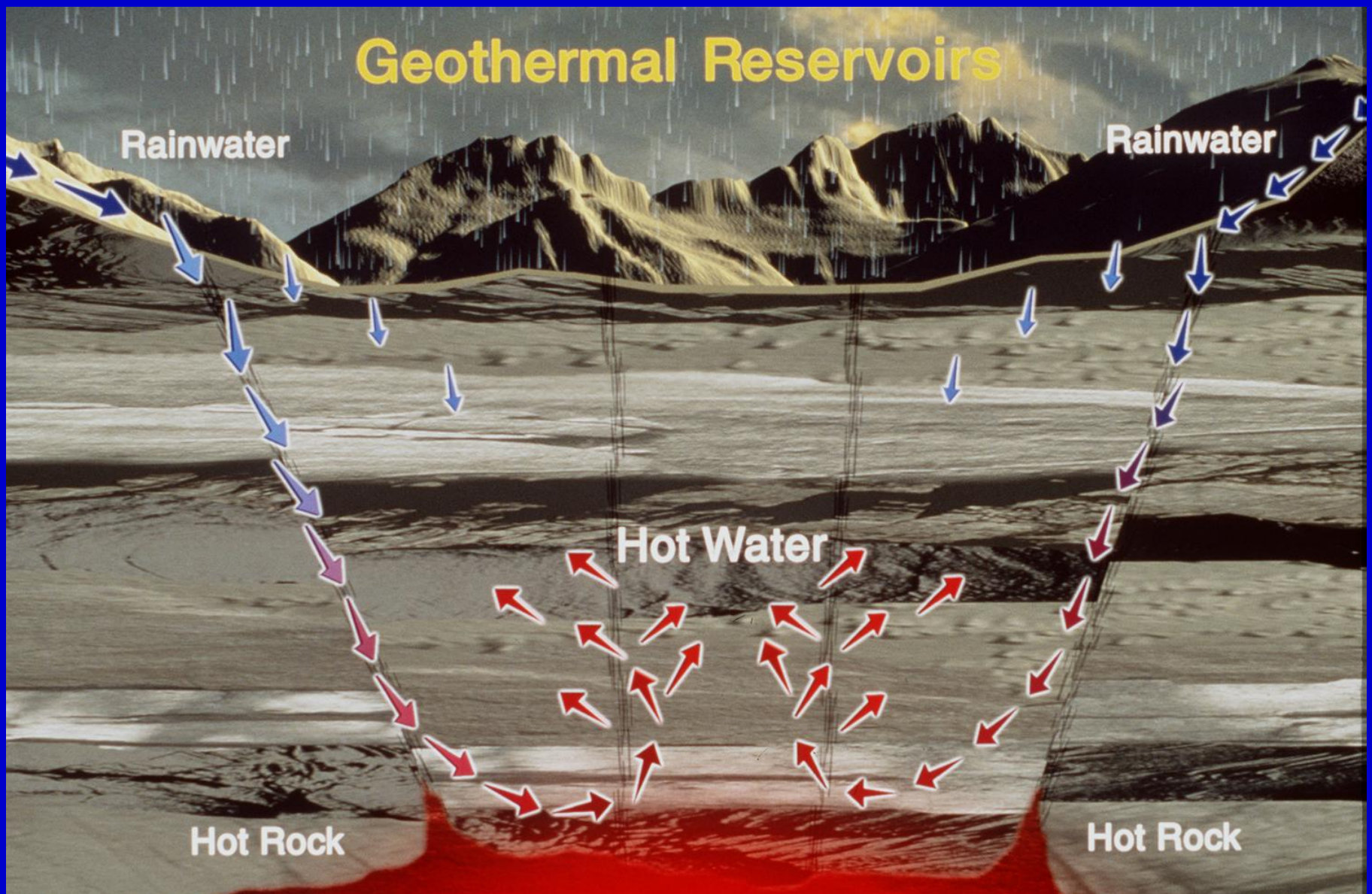


# Plate Tectonic Processes





# Geothermal Reservoirs



# Geothermal Energy

How do you use it?



# Uses of Geothermal Energy

- **Generation of electricity**
- **Direct use of geothermal**
- **Geothermal heat pumps**

# **Worldwide Geothermal Use**

**8,900+ megawatts of electrical capacity**

**24 countries**

**56,800 Gigawatt-hours electric/year**

Bertani, 2005

**27,800+ thermal megawatts of direct uses in  
more than 70 countries**

**72,600+ Gigawatt-hours thermal/year**

Lund et al, 2005

# **Countries Generating Electricity with Geothermal Resources**

**Argentina**

**Guatemala**

**Nicaragua**

**Australia**

**Iceland**

**Philippines**

**Austria**

**Indonesia**

**Portugal (Azores)**

**China**

**Italy**

**Russia (Kamchatka)**

**Costa Rica**

**Japan**

**Taiwan**

**El Salvador**

**Kenya**

**Thailand**

**Ethiopia**

**Mexico**

**Turkey**

**France (Guadeloupe)**

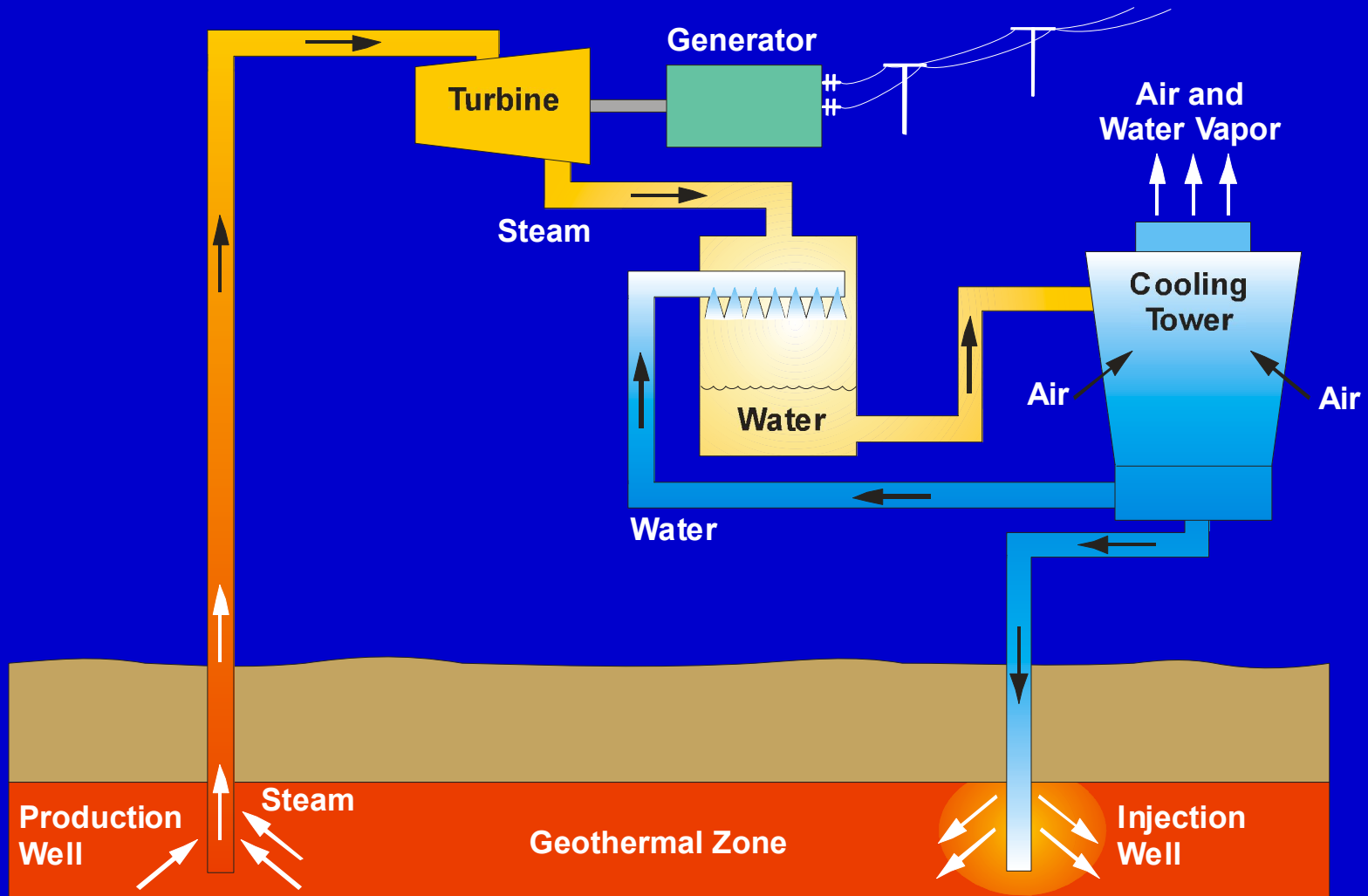
**New Zealand**

**United States**

**...and new geothermal power plants are planned in  
several other countries**



# ***Dry Steam Power Plant***



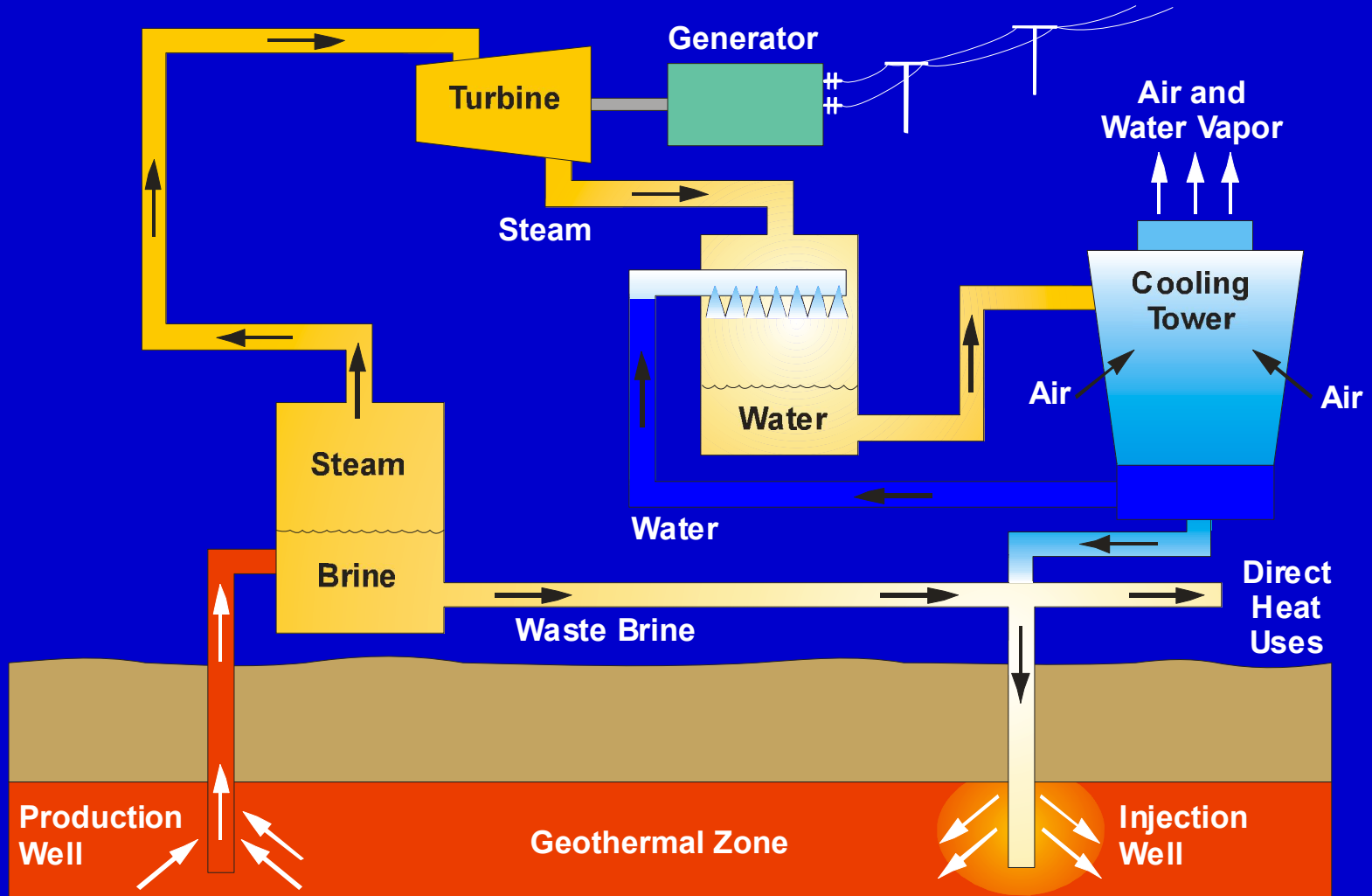






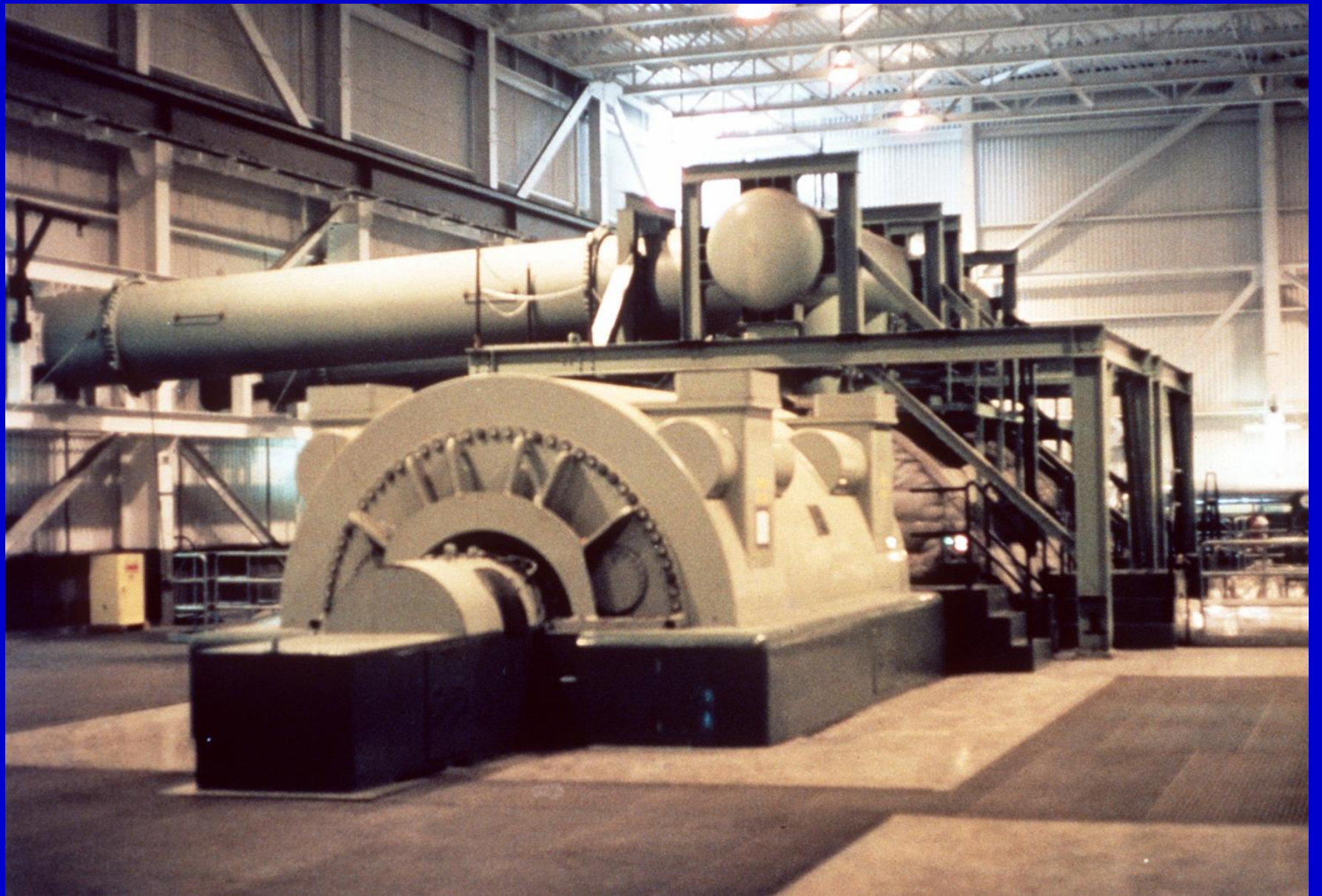


# *Flash Steam Power Plant*

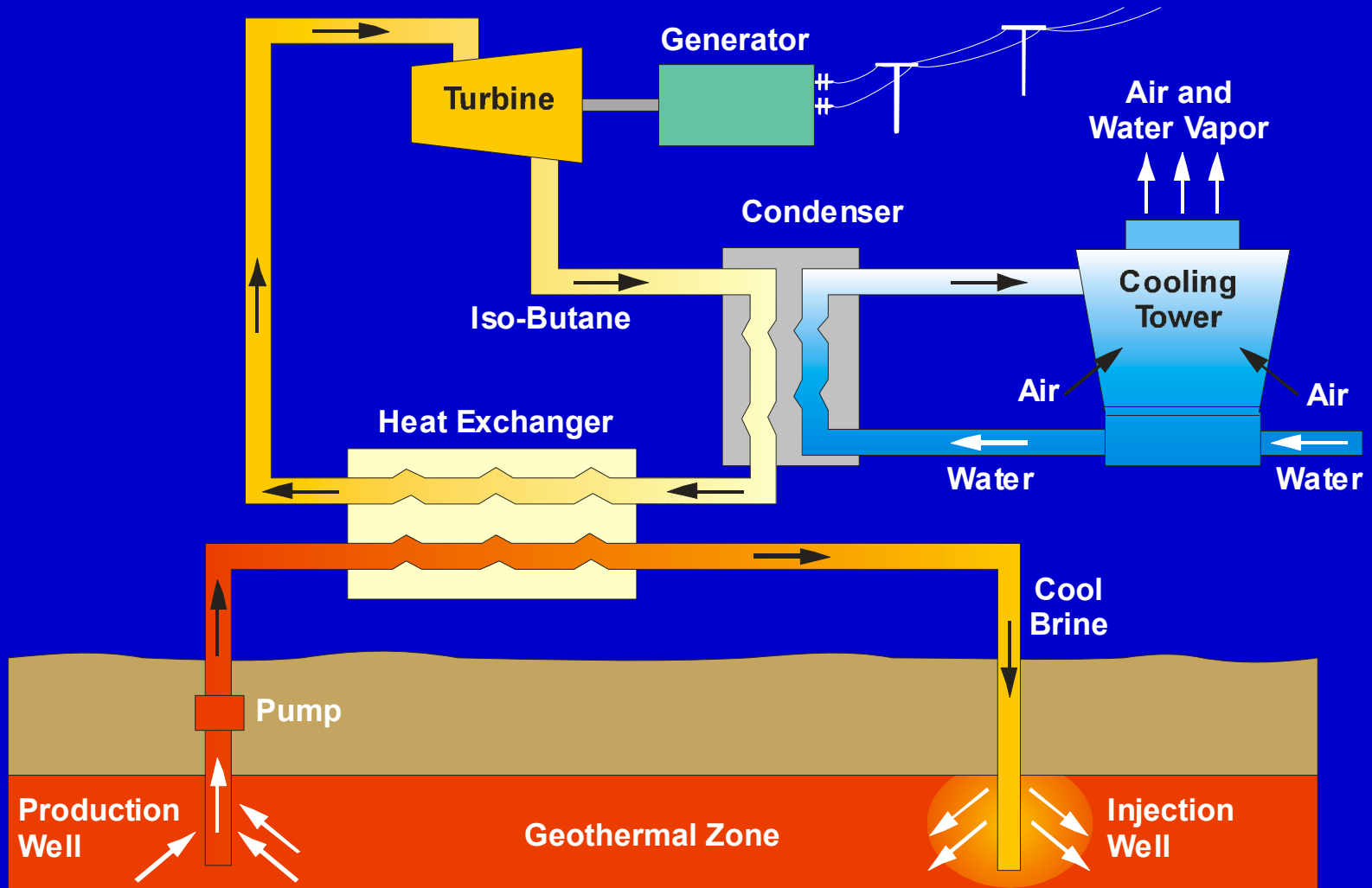








# *Binary Cycle Power Plant*







# Recent Directions

- **Generation of electricity from low-temperature resources**
- **Electricity co-produced with oil and gas**
- **Enhanced production through stimulation**









# ***Direct Uses of Geothermal Water and Its Heat***

- **Hot springs and spas**
- **Aquaculture**
- **Agriculture**
- **Residential and District Heating**
- **Industrial Uses**





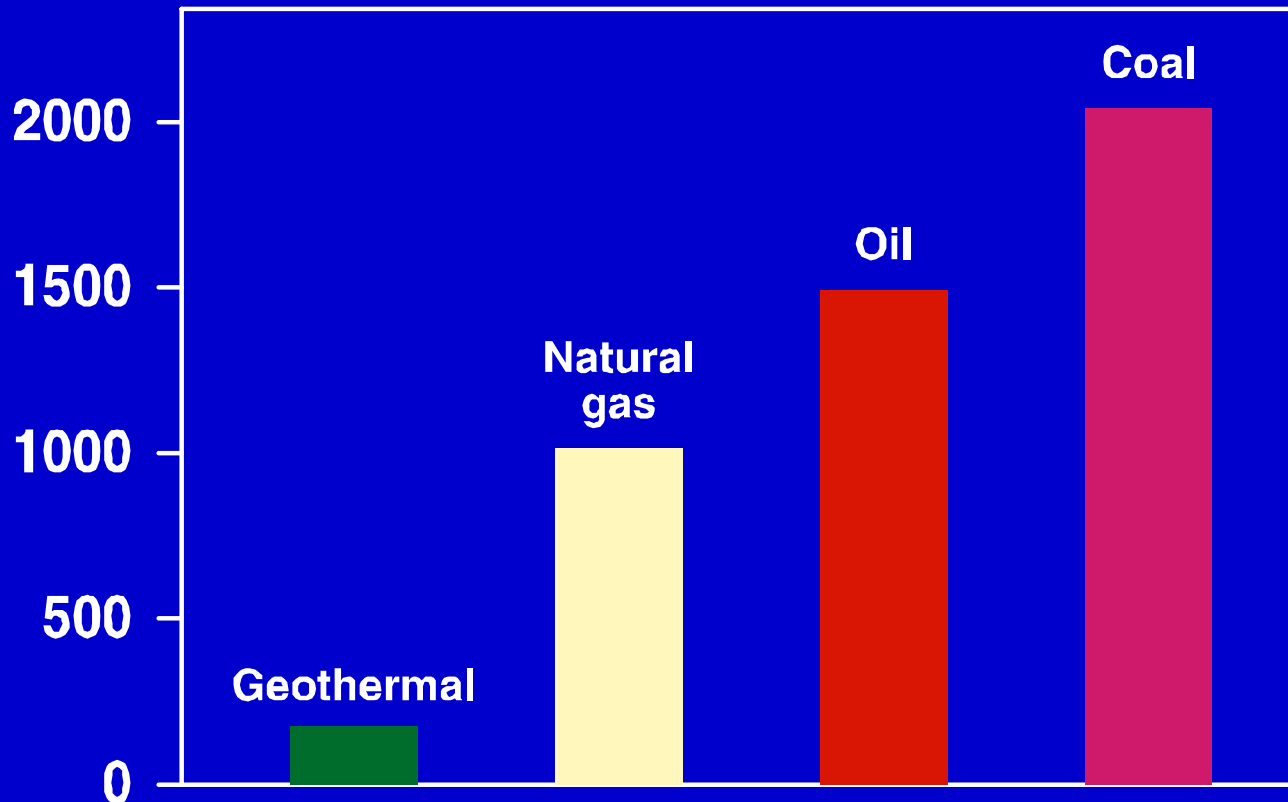




# ***Environmental Benefits of Geothermal Energy***

- **Binary plants - no emissions**
- **Flash plants - low emissions**
- **Most plants - no appreciable solid waste**
- **Small land use over project lifetime**
- **Low visible impact**

# CO<sub>2</sub> Emissions Comparison (lbs/MW-hr)



Source EIA 1998; Bloomfield and Moore 1999











# Age of Seafloor

